Jennifer Stock: This is Jennifer Stock and you're listening to Ocean Currents and on this show I host experts in the field that bring us news about the ocean, this blue planet controls our climate and weather, provides food and recreation, and provides a home to so many plants and animals. I bring this show to you from the National Oceanic and Atmospheric Administration, Cordell Bank National Marine Sanctuary, which is just off the Point Reyes National Seashore coastline, north of San Francisco and if you want to hear past episode of Ocean Currents, please visit cordellbank.noaa.gov. C-O-R-D-E-L-L B-A-N-K dot N-O-A-A dot G-O-V. We have past episodes and you can subscribe to a podcast on that website.

So, today, this time of year on the California coast we notice a shift of weather on land and in the water. For ocean lovers it can be cause for celebration because the food web starts to take off or it can be a curse if you actually want to be on the water. The winds that barrel down the coast this time of year are one of the drivers on the food web on the California coast and you know it's upwelling season when you're at the beach and your hat is 50 feet further down the beach, you've got sand in your ears, your eyes, your nose, and at the edges of your binoculars. Sometimes by wind sailors an offshore jelly with a little blue sail will wash ashore and that signals that something is happening.

Something is happening and it's amazing what scientists are learning through ocean technology and modeling. Today I'm talking with Dr. John Largier an oceanographer who is a professor in coastal oceanographer at UC Davis at BML, Bodega Marine Lab. We'll be talking about all of the forces that shape this productive region when we come back. Stay tuned.

(Music)

Jennifer Stock: John, are you on the air with us?

John Largier: Yes, I'm here.

Jennifer Stock: Oh, welcome! Thank you for joining us today. Just to give some background on John, John has a PhD in oceanographer from the University of Cape Town, South Africa. John's research is in coastal oceanographer and ecology, specifically field-based study of water motion and the transport of water-borne material. John's interest in the environmental and ecological issues include larval juvenile dispersal, coastal water quality, such as beach pollution and primary productivity including harmful algal blooms. John's

long-term goal is to better understand the coastal ocean systems to obtain an integrated view of how the diver's components, processes, and scales fit together. We're very lucky to have you on the show today, John. Thanks for joining us.

John Largier: Oh, thanks Jennifer. It's a pleasure to be here.

Jennifer Stock: So, can we just maybe set the scene first and can you start by just describing what the different oceanographic seasons throughout the year are like here off the coastline?

John Largier: Actually, you just described the characteristic season, the upwelling season, a blessing and sometimes seems like a curse as well. Very similar seasons are seen elsewhere on South America and Southern Africa, Northern Africa...same latitude on the west side of continents. All of these places have the upwelling seasons, but it's part of a rhythm of the year. So, we know, right about now, March or April, the winds turn...become strong north and the cold water upwells, but come late summer and getting into fall when the weather gets nice here, the ocean gets calmer as well.

Along fall season or fall transition, really, to warmer weather, warmer water, and quieter winds this time on the coast for humans, at least and then probably a third season, of course, is the winter storm season where we tend to get the westerlies come through and the rain and a lot of runoff from the land and that sort of dominates that season and then getting back to upwelling, quite a sudden, supreme transition we're seeing which may change from almost one week to the next from a winter to a spring or upwelling season. So, really three seasons in the ocean is what we see.

Jennifer Stock: And do you think...do you feel locally, recently that things...we've transitioned? I've noticed this wind we've had in the last week and it just seems very strong. Do you think this is the beginning of the upwelling season?

John Largier: Sure feels like it. Even a weeks back, it seems quite early this year. In the ocean what we know...we don't have online data. So, we look sort of retrospectively. The bottom water down at depths of 100 meters or so gets cold certainly gets colder than it was and stays colder. So, while you'll get these pulses of wind, there's a certain change that happens deeper down over the continental shelf where the cold, really deep, high-nutrient water will get onto the shelf and that really marks the spring transition and this shelf off northern California has been studied probably really intensively now for probably about a quarter of a century, since the 80's, and

we have this spring transition in some years happen as early as late February and other years happens as late as May, but typically in this March, early-April period, we start seeing that and that's the high-nutrient water that, of course, fuels the system.

Jennifer Stock: So, what are some of the factors that really change that year to year? What really is the first thing that really triggers this system from going?

John Largier: Well, that's a good question. The most obvious change is the El Nino cycle that we have come to know pretty well in the last ten or twenty years. So, in 1998, for example, was El Nino and then people came up with the word La Nina being the alternative period, which 1999 was, a very strong upwelling wind and it does really refer to the season as a whole and exact timing of when it starts is not that well known and we really learned that last year, but also particularly in 2005 when the upwelling seemed to start in April and then in May it was gone and we had a lot of birds and fish who went hungrier that year.

Actually, the Cassin's auklet didn't even have one chick, I think. In 35 years of monitoring the Farallon Islands that's the first time that's happened. So, that was not an El Nino year. It was the ??? pressure system in the northern Pacific exactly why it switched upwelling winds off for six weeks. It's not completely clear and this is all what I think of as the rhythms of the ocean and there's not just the one 12-month seasonal cycle, but there are these, what we know very well living on the coast, there are sort of one week almost cycle of plans. So, what we call synoptic variabilities.

The wind blows for three four days and stops for a day or two and blows for five days and stops for half a day. That's another rhythm that we get and then would...then there are other ones which we're not...we're still learning about, which might be twenty or fifty days long and I would say we don't fully understand those.

Jennifer Stock: That's what's so amazing is it's constantly changing science and everybody wants to know everything, but we really don't know. Can you talk a little bit about one of the variables, the...I've heard about the Pacific Decadal Oscillation and is this...this is one of the shifts that is fairly normal and can you just describe what it is and what shifts between those ten years?

John Largier: You're right. So, as we study the ocean more we're starting to and for a longer period, we've got into realize, of course, that there are longer rhythms as well and they go way back to the Greeks and we

knew about tidal cycles and day-night cycles and our science came to understand the wind science and the seasons, but now they start collecting longer records, we learn what a lot of people, I think, have known maybe in more traditional knowledge systems is that there are these long-period cycles.

So, we have the El Nino that some...in every several years there is...in Peru there are more fish and every other few years there are less fish and now we've seen longer, like decadal oscillation. There's a specific decadal oscillation, it's an Atlantic decadal oscillation. We've seen rhythms that get 20 or 30 years long. So, first probably noticed in the crush of the sardine fisheries and some of the other fisheries in ?? back in the 40's and 50's was...people started calling that a regime shift and then again in the 70's and we're starting to see this as a, you know, maybe 10 or 20 year decadal pulsing in the whole, in the north Pacific, but it's really tied into the Earth as a whole, which is pulsing and breathing. That's probably the best way to describe it.

There are some of these cycles...El Nino has become well described in terms of the pressure created across, along the equator between the eastern Pacific and the western Pacific and that's ??. The Pacific decadal oscillation is more of a difference between the northeastern Pacific...I mean the northern Pacific and the equatorial Pacific, but the actual mechanism is...although we recognize it's happening, we're not trying to understand exactly what is the mechanism of what's driving that.

Of course, underlying all of this is a circular trend, an ongoing trend, not a cycle, but the whole climate change idea. It's very difficult to see through all these cycles that lie on top of it.

Jennifer Stock: So, it gets really confusing. Like you were saying, that the last two years we were seeing very low productivity and the food web was responding to that. We had hardly any blue whales here and we had humpback whales feeding on a lot of fishes and this year, there was some talk that we were seeing El Nino-like conditions, yet it wasn't in an El Nino, but typically what...the El Nino conditions that we would receive up here, you said earlier that there may be very productive waters down in Peru during an El Nino year and so, why is that? Do they have a different water mass down in Peru as opposed to this one?

John Largier: Right. No, in actual fact it's....they are in sync with us in Peru and the El Nino is not a good time for them and so there...some of these anomalous periods, these unusual periods are El Nino-like

because they're warmer than normal, but it's...they're not all..all of these warm anomalies are not all due to the same mechanism and that's what we're starting to see now, that there are warm periods that maybe are a different mechanism. Technically, El Nino really what happens is all the warm water that crosses the Philippines and on the...get my compass right on the website of the Pacific....suddenly, if you like, sloshes towards the Americas, crashes into them then goes north and south.

It's a very simple explanation, but we see the warm, tropical water coming up into southern California and even sometimes further up towards us and at the same time going south toward Ecuador and Peru and that's where it actually has a bigger impact there than it does here...

Jennifer Stock: I see.

John Largier: ...but quite similar in both hemispheres.

Jennifer Stock: One thing I want to mention is, we're in the California current ecosystem and Peru is also in a very special system. These are part of eastern boundary currents. Can you talk a little bit about the significance of eastern boundary currents, where they are, and what are some of the features of them?

John Largier: Right. Yeah. So, again, patterns. These upwelling seasons and then they happen in special places in the world, the eastern boundary currents. So, it's really...the best way to describe it is middle-latitude, you know, what are we at here? Around 58 degrees north then you go to 58 degrees south off the coast of Chile and you'll get a very similar system or you go to ?? off Southern Africa, but you go to Lisbon, for example, 38 degrees north off the west coast of Europe and all of these west coasts are subject to what we call equatorward winds.

In other words, in the northern hemisphere, they blow from the north towards the south and in the southern hemisphere in the other direction and because of the rotation of the Earth they all bring about an upshore transport of surface water and so that whole region, in our case, you know, running from in summertime as far north as Vancouver Island and in wintertime as far south of Costa Rica or definitely down...maybe not that far, but definitely down mainland Mexico is the region of upwelling and of flowering almost, is the word used sometimes for it and disperse nutrients over a large area a huge eastern boundary current system hundreds of miles offshore will soon be productive and you'll find the same.

Our system is called California. Off South America it's typically called the Humboldt system. Sometimes people call it the Peru system and South Africa, they call it the Banguelas system, runs up Namibia and Angola and then the Canary system which runs the Canary Islands, but also close to Morocco, Portugal, Spain and then down south as far as Senegal.

So, those are the four primary systems. There are a couple of other smaller ones.

Jennifer Stock: And I just read and I want to see if it compares to what you know. These four systems, they cover less than 1 thousandth of the world's ocean surface, yet they produce over a third of the world's fish for economic value. Does that sound about right?

John Largier: Depends a little bit on how you count it, as always with numbers, isn't it?

Jennifer Stock: Right.

John Largier: The numbers that I normally use are one percent of the ocean's surface so that would be one-hundredth...

Jennifer Stock: Right.

John Largier: ...and twenty percent of the fish.

Jennifer Stock: Oh, 20 percent.

John Largier: But, that's still a pretty good fact, isn't it? It's 20 full-depth amplification.

Jennifer Stock: Wow, so these are the most productive regions. It's interesting too because now that we have all of these new technologies and we're tagging animals and finding out where they're going there's like these beelines for these productive areas for certain species of birds and mammals. So, they're telling us something about these areas as well.

John Largier: Yeah, lots of migrants that come in, as you said, birds and big fish, tuna, whales moving through it and it's a, sort of, vegetable garden, maybe that people or animals and fish move in and out of and then of course, there are a whole bunch of species that live their entire lives within it and there are some interesting stories there as well where they need to time their lifecycle, you know, the annual...their annual rhythms to the upwelling because one of the

classical things is trying to understand now the coastal fisheries and the idea of some marine protected areas is part of these coastal populations live in a system when in the upwelling season, a few little drifting larvae or egg or juvenile fish or something like that. The currents are always offshore.

So, for some species it's a good time to be in the water column and other species it's not a good time to be in the water column. So, syncing your lifecycle to the environmental cycle.

Jennifer Stock: That's probably why so many of these invertebrates and fishes cast so many eggs and sperm to have as many chances as possible to survive.

John Largier: It sure seems like it, seeds in the wind. Maybe it's, well, you know, how they've evolved. Maybe their best strategy is to, as you say create lots and lots and lots of eggs and some of them come back, but it seems to be cleverer than that, the systems.

Jennifer Stock: Do...during some upwelling years in the past there have been days where it just blows and blows and blows and blows and I've heard that when that happens and these surface waters are pushed offshore, a lot of the larvae also get pushed off and can go all the way across the Pacific or away from these productive regions. Have you studied much about this larval transport that happens during the upwelling?

John Largier: Yeah. So, we...with colleagues we...that is really a classical...not classical...a very contemporary question as we try to figure out...we concentrate more on the larvae that come back to the coast. So, you know, if a parent has a million eggs or something, they can go just about anywhere and the population as a whole has many, many more than that, but the question is how do some of them stay here or go away and come back to the coastline and there are a whole lot of different strategies there. The...two of the key ones are probably that it doesn't upwell everywhere along the coast. So, there are these spatial patterns, capes and bays, for example, to the shoreline in Drake's Bay often is not upwelling as strongly as it is, say, north of Point Reyes along the coast up towards Point Arena and then the other pattern that's important is this...it upwells for a few days and stops...and upwells and stops and different organisms figure out different ways of taking advantage of that.

Probably the most interesting is the primary production. So, not the larvae, but the actual phytoplankton, the little drifting plants, that suck up the nutrients and they don't have much chance of

swimming against currents. So, they tend to get carried offshore, but then the wind stops blowing and they tend to come back onshore caught in a little eddy behind a cape. So, again, that rhythm is essential to making systems productive.

Jennifer Stock: And so the wind blows for a couple of days and it really is pushing and then it somewhat relaxes a little bit or some of it comes back. How many days does it take for those nutrients that have been brought up from the bottom to the surface waters to help fertilize some of the microscopic phytoplankton in the water? What is that lag time between the wind...

John Largier: It's...yeah, that's really interesting, the time of upwelling and what works and what doesn't. So, the upwelling itself takes maybe a day to really get going, but the question is that upwelling water from a depth of 10, 20, 50 meters and is that water full of nutrients or not? So, you would have upwelling along some coasts...almost every coast in the world has upwelling events, but they're brief and they're not a persistent, but the thing here is it that we get this high-nutrient water coming right up on to the shelf and that's important to the spring transition.

In an El Nino year, you might have an upwelling wind that is upwelling warm, low-nutrient water. So, it's not any good, but it takes about a day for the upwelling to start. Then, it might blow for a few days, maybe even a week is ok. So, it blows much longer than that and everything's been blown off the shelf and it's way gone far out to sea and that's no good either. In fact, there are probably ?? on the coast of Namibia is a good example. It almost never stops blowing. It just blows incessantly and there is not a lot of marine life on the shelf because it's all blown away. It's quite fascinating.

Jennifer Stock: So, it takes a couple days for that to get going and would you say here on the west coast that the peak upwelling is really happening north of us, Point Arena area, and then it drifts down during that relaxation time down the coast this way?

John Largier: That's the way we're seeing it. Although, not to make generalizations, so the spatial pattern is one of upwelling centers and Point Arena is probably the king or definitely one of the princes. Cape Mendocino would be another one. As you get further south, Point Sur. Ano Nuevo, which is just north of Santa Cruz is a smaller one and in all of these upwelling systems, whether they're in southern Africa or South America, you have the same...these sort of cores, almost fountains, of upwelling. The thing about Point

Arena that is really unique is that it just keeps going, even when the wind stops for a while and chooses it's direction of currents and the bottom and so on, Point Arena really keeps going and then as the water comes up there, it might come up elsewhere as well, but it comes up most strongly there, it then flows south.

So, upwelling causes very strong southward current and that should effect the...currents are stronger along the coast than offshore.

Jennifer Stock: Oh.

John Largier: And so, water that comes up to the surface at Point Arena may be five days later than it will be down at Point Reyes and crossing over Cordell Bank, which is so, as you know, this is something we're trying to understand better, that Point Reyes, Point Arena, is a source of upwelled water. Five days later it comes over Cordell Bank. It's not full off phytoplankton of these drifting plants, which have been the food supply to the bank. The food to the bank is really...you put us in the right place, Jennifer, I think.

Jennifer Stock: Well, I'm trying.

John Largier: But then, when things relax out there over the outer shelf or a certain distance offshore, things tend to go south, but near-shore around from Point Reyes up to Bodega, we tend to see strong northward flow of warm water. We'll see San Francisco Bay water coming up past Bodega and even up as far as Point Arena. Very seldom, but sometimes it will do that.

Jennifer Stock: Wow. For those just tuning in, this is a little late, this is Ocean Currents and my name is Jennifer Stock. I'm talking with Dr. John Largier from the Bodega Marine Lab, an oceanographer, and we're talking about upwelling and productive systems here off the coast. So, do you think that the shape and the contours, I mean, I've heard this definitely around seamounts and what not, but does the shape and the contours of the seafloor really aid in the productivity levels? Is there a specific contour off of Point Arena that really accelerates and keeps that upwelling going?

John Largier: Yes. Definitely and in both the examples you're talking about the one that's...seamounts in general. So, outside upwelling areas defined as isolated seamount, it can be pretty important in a slightly different way, but even with an upwelling system you will find that the headland...that the upwelling is...the headland being the cape, but the promontory...can't even say that word...you'll find

that the upwelling is emphasizes, exaggerated, enhanced there. So, Point Arena....it happens for two reasons. The one is the quite high coastal mountains or coastal hills and you get an acceleration of the wind around point arena and just south of it, much stronger winds there than almost anywhere off of the coast between Point Arena and probably Bodega, but particularly up towards Point Arena and then in addition to that you have the submarine, the undersea topography, which also creates a headland or cape and that makes the currents speed up and enhances the upwelling. Same thing, as I say, down in Point Sur or Cape Mendocino, Cape Blanco is another one further north in Oregon.

Jennifer Stock: And then it comes down the coast and then there's a big transition area between, it seems like, the Monterey Bay National Marine Sanctuary and Channel Islands National Marine Sanctuary at Point Conception. What's going on there to the California current that's pulsing down the coast and then it hits point conception and what's going on down there?

John Largier: Well, this is great...describing the way they fuel all these systems. I started off talking about how things change in time, that is, these rhythms year to year or season to season or day to day and then in space is the same idea. There are these patterns, large scale patterns, we talked about before, primary upwelling regions, you know, pattern....I mean, big areas a thousand miles or more that are long and there we've been talking about smaller-scale patterns, Point Arena to Point Reyes, a hundred miles past and now we're talking about something in-between where the winds that howled on the coast remain alongside the coast down to Point Conception and then they tend to separate from the coast.

So, the whole, what we call the Southern California Bight from Point Conception, or let's say Santa Barbara down to San Diego. As you know, the winds don't blow as hard there. Well, they're blowing, but they're further offshore and so that whole southern California area...I always say that it's upwelling or the lack of it that gives the real estate so much value there because the water is warming, the winds are weaker, all of that and then these winds actually come back to the coast again, somewhere, really, around the border. By the time you get down to Ensenada in northern Baja, the winds are quite strong again. If you go down on the coast of Baja, it will be a little bit like Bodega. It will be windy and cold and misty. Quite strange, actually.

Jennifer Stock: Is there a current that's coming from the south that is mixing into that California current into that bight there because pictures that

I've seen of sea surface temperatures and chlorophyll it was just these incredible swirls going on of different colors.

John Largier: Yeah. There is definitely counter-currents. There are quite a variety of them. So, we talked about one of them up in the Bodega region coming from Point Reyes when the winds relaxed, but in the southern California Bight between Point Conception and Santa Barbara and San Diego there's quite a strong counter-current, in particular in the Santa Barbara Channel, like you say, the swirls you see in the satellite imagery, warmer water coming up north past Santa Barbara and then crashing into the colder water then swirling around the Channel Islands. You find that out at Channel Islands are cold and more sort of upwelling like and the ocean scent in the Channel Islands are warm and more, you know, temperate, but there are other counter-currents.

One that we don't see is perhaps the most important. It's an undercurrent and it flows along the edge of the continental shelf. So, you know the continental shelf is this big platform, if you like, and the depths go down to a hundred, two hundred meters and extend quite far offshore around here at Point Reyes, Bodega area. It may be fifty miles offshore and then you drop off that shelf and that drops down a thousand meters down into the abyss even more than that. Along the edge of that continental shelf, there's a current only about a hundred meters down, but then it extends from a hundred, maybe, to three hundred meters. A big, strong current going northward the whole way up the coast of California and that brings very important nutrients, but also other materials.

Jennifer Stock: Wow. There's so much going on, so much more than meets the eye.

John Largier: Yeah.

Jennifer Stock: When I...I used to live on Catalina Island and, you know, the diving at Catalina was so different than the northern Channel Islands. It really was testament to that Catalina's a little bit in those warmer waters and the northern Channel Islands are much colder water, more rockfish for sure. We saw different hydrocorals and cup corals, a lot of cold water rocky root species where down in the Catalina area saw a lot more garibaldi and kelp forest-like areas.

John Largier: Right. We're trying to not only understand better, but, sort of, map out better what I might call the water habitat or the pelagic habitat and when we think of habitat in the ocean we think about, is it rocky or sandy? Is it shallow or deep, but there's some areas which are more characterized by cold water and high nutrients and others

by warmer water or...unfortunately some areas are characterized by pollutants, but there are different zones up the coastal ocean. So, for example, I have a graduate student working with me on the Channel Islands trying to understand the different distribution, as you were talking about, the different fish and the different kelp and the different invertebrates who live there to try to understand that distribution in terms of the oceanography.

The one end is cold and subject to high-nutrient water and the other is getting totally different water and are ten miles away from each other.

Jennifer Stock: It's amazing. Well, it's just about six o'clock. We need to take a short break, John, but when we come back, I'd love to hear a little bit more about some of the technology and how we are mapping out the water since it's so hard to see and there are some amazing tools in place. So, please stay on the line for a few moments. We're just going to take a short break.

(Music)

Jennifer Stock: And John, we were just talking about sort of mapping out these areas of the ocean and I just...one thing that came to my mind was the idea about these fronts of water and what happens when two different masses of water meet? What are some of the things that happen along those areas that are defined as fronts?

John Largier: The...well, first of all when two different groups of water meet, two different packages of water, typically one of the waters is a little bit denser, a little heavier, than the other, which might be a little bit lighter and so, what tends to happen is one goes underneath the other and then that subduction or in that plunging underneath, the surface waters come together to form a convergence line, which is often why when you're out on the ocean you will see a foam line where two different water masses meet. So, one side might be a bit bluer than the other, but often there's a foam line there. Typically you'll find this at the edge of...most strongly at the edge of a river plume, for example, flowing into the ocean or into sea when the tide flows out from San Francisco Bay out of Bolinas lagoon, but you'll also find it, for example, at Point Reyes where the water is flowing south from the north coast and interacting or meeting the water that's warmer caught in Drake's Bay area.

So, this bringing together at the surface brings a lot of food and particles and...together and the fish start feeding on that and the

birds start feeding on the fish and you create this whole little...I don't want to call....ecosystem is the wrong word, but this whole little system near...it will only be transient, but it's a place with things...it's like the dining room table where things come together for a while and have a meal and then disperse again until they find some other front.

Jennifer Stock: Right. I've seen that a lot. Being out at the Point Reyes Lighthouse occasionally, you'll look out and you can definetly see these fronts of water where you'll see little pieces of debris and that foam and different birds feeding on there. It's an amazing little eco...

John Largier: And even whales sometimes are...

Jennifer Stock: ...area.

John Largier: ...swarms and it can have so much happening on the interfaces.

Jennifer Stock: Wonderful. So, I want to hear a little bit about some of the technology. We use so many different tools that we're...mapping all of this. It's very easy to just say all this, but obviously there's been a lot of work and research and modeling put together to understand just the basics. What are some of the tools that you're using to understand these currents and fronts and movements of water?

John Largier: So, the...probably one of the first technological developments in the modern time, that gave us a real insight was satellites where they look down on the ocean and get a much bigger view of the ocean than we can and in particular they sample the radiation, for example, the surface temperature will emit radiation more from where it's warm and less from where it's colder. So, a satellite way up there in space will get this picture of cold and warm water and you'll see the swirling of water, which you described earlier and I think probably many people around here have seen those satellite images and then after that, the satellite imagery started looking at ocean color and, for example, where you get phytoplankton, the water will be greener than where you don't get it and you see these same swirling patches, but you're starting to get an idea of where there's food and productivity and where there isn't.

That really started us thinking about the ocean in different ways. These ideas of upwelling centers, I was talking about the river plumes, and I didn't use the word earlier, upwelling shadows, in the bays of Monterey Bay and Drake's Bay and even up in Shelter Cove and north of Fort Bragg, you'll get these upwelling shadows

or sort of quieter areas. So, we see that from the satellites, but it doesn't tell us too much about how the water is moving or why it's like that...a whole slew of different technology, but the most recent and exciting one is the high-frequency radar system that the state is investing in and working with a number of us at different marine research groups along the coast from...the whole way from San Diego and actually, in fact, even collaborating with some people in Mexico and the whole way up to Oregon and collaborating with people in Oregon and this is a system...very low power radio waves that go out about...the most the systems are using are going out about 40 kilometers and maybe 30 miles and they're bouncing off the surface of the ocean and through a mixture of Bragg Scattering, if people know what that is, and Doppler shifting, we get an idea of how fast the currents are moving on the surface of the ocean.

So, we can...we now have systems set up from Gerstle Cove or halfway up to Arena and then down past Bodega, San Francisco, a little bit into San Francisco Bay down into Monterey Bay and similarly in southern California, colleagues have it from Point Conception, I think they have it set up now the whole way down to the border and the rest of the state is getting filled in. So, you will...you can see every hour, really, a map of surface currents. So, now we're not only understanding what's going on, but in real-time we can start getting some really useful information on this natural pulsing of the ocean as well as river plums that might be carrying foreign material, maybe oil spills or search and rescue, if there was an accident and somebody was lost overboard where they might be going. So, this system is just coming up now.

It's really pretty exciting operationally and scientifically.

Jennifer Stock: Seems like a really important tool for tracking oil if there was an oil spill and being able to model where is it going to move first so response can get on the ground and be ready for that or respond to it wherever it is.

John Largier: Very much so. We interacted with different agencies in NOAA and different local and state agencies and I think the sanctuary, well I know the sanctuaries were involved as well last August, the Safe Seas Exercise where we're trying to see how could this information be used to improve oil spill responses. It takes a while to get it all set up so it's ready to go when unfortunate...saying when, maybe I should say if there is another oil spill around here.

Jennifer Stock: Right. This is also useful information too, a couple of years ago wasn't it with the...there was a proposal to dump sewage from Santa Rosa off of Bodega and I believe this modeling was presented to the board to show them what would happen to that sewage if, indeed, they did dump it.

John Largier: Yes. That was prior to me getting up here and I believe the plan was...the consideration was to discharge into Estero Americano, which would then flow out into Bodega Bay and then be carried away by the ocean currents and where would it go? It'd be very useful for that and it has been used in southern California for looking at ocean...out for issues and probably we might do some here as well, but on the whole the ocean outwards, of course, discharge at depth and it doesn't get up to the surface, which is giving you surface current. So, this is very good for river plumes, which go out on the surface.

Jennifer Stock: Yeah, especially since we'll be starting to learn more about some of the contents of the river plumes just with monitoring more water quality offshore 'cause we are a partnership. Cordell Bank National Marine Sanctuary and Bodega Marine Lab were putting a buoy in, hopefully this year at Cordell Bank and you've been very instrumental in making this happen, John, what are some of the instruments that are going to be on this buoy that are going to help some of this science move along?

John Largier: Right. Yeah, this gets back to how we talked about Cordell Bank maybe being a critical location in the ocean. So, that, in itself, is a good reason to have a mooring there, but then...or a buoy and the second reason is we really want to understand that environment and why it's so special in the bank and that may be just in a perfect place to receive a ready supply of food. So, the...probably these three key things that we would be measuring there. The one is all of the currents over the bank. Is the water normally coming to the bank from the north or the south or the east or west and this high-frequency radar tells us at the surface that it's coming from the north, coming from Point Arena and what we now, this mooring on the bank, there will be a buoy on the surface and then it'll be tethered to...in place with an anchor and then there's a profiling current meter that acoustically measures the currents right through the water column from the seabed up to the surface and often, as I mentioned earlier, we might have northward currents down at depths and southward currents at surface.

So, that's the one very important thing we will measure and that tells us where things are coming to from the bank. The second

thing we'll be measuring, just simple temperature and salinity of the water and that tells you something about it. Upwelled waters, as you know, are cold, but they also, the salinity, the salt content is a little higher. So, if we measure that we know the origins of the water even if it's warmed up. If it's a high salt content, a high salinity, then we know it was upwelled water and it did used to have a lot of nutrients in it and then the third important thing is if you measure fluorescence in a certain wave band or wave length, it's a very good estimate of how much phytoplankton is in the water because it's...actually an estimate of how much chlorophyll, which is one of the portraits that you know as the pigment and that gives you an idea of how much phytoplankton is. It's...so when there's a bloom or a lot of phytoplankton around you will get high fluorescence values.

So, we'll be able to then really have a monitoring, you know, hour by hour of the conditions over the bank and this is excellent because it then becomes a partner with a similar system we have at the marine...Bodega Marine Laboratory, but right near the shoreline where we see quite different conditions near the coast as to...out at the edge of the continental shelf.

Jennifer Stock: Sounds really exciting to be able to compare those two and be able to learn a whole lot more about that offshore ecosystem.

John Largier: It's...I think it's invaluable, particularly when it's put together with monthly trips or even more often, but the regular monthly trips that the sanctuary conducts first to, again, measure temperature and salinity of the water, but also survey mammals and birds and linking those two together that's important and then almost every day we get a good satellite image of the region and then every hour we have the surface current from the radar. So, all in all, we're getting...we're going to have a very good picture of this area and not only for Cordell Bank, but this is still like the upstream end of the Gulf of the Farallones.

It's then the water then flows south into the Gulf of the Farallones, past the islands and then maybe getting pulled into Drake's Bay and...we're really trying to understand this area where I suggest, briefly, if you look at satellite imagery of the ocean color, where the green water...there's a region from Bodega down to Monterey shines out like a bright, green light if you look at average satellite images. So, it really is the most productive part of the coastline, at least from south of Point Conception up to near the...probably up to Juan de Fuca. It's really a very, very important place and we're starting to unravel the oceanography quite nicely.

Jennifer Stock: That's wonderful and that's really why these national marine sanctuaries were established was because of that incredible productivity. One thing I want to mention is the buoy is going to help complement a lot of the information, as you mentioned, the Cordell Bank Sanctuary has an ocean monitoring program that goes out monthly and the observers are watching for seabirds and mammals and one thing they saw this past year was that a bird that's usually fairly common out there, the Cassin's auklets, which breed on the Farallones, were pretty much very, very low numbers and corresponding data with the Gulf of the Farallones beach watch surveys, the Gulf of the Farallones National Marine Sanctuary does these beach watch surveys, their Cassin's auklets numbers on the beaches, meaning dead birds, was high. So, it was really interesting that those two, of course, correlated so closely and the buoy, I think, is going to help fill in a lot of information for these stories that are happening year to year.

John Largier: Yes, indeed. We don't have a good enough idea of what is normal in inverted commas because every year is different, but what is truly anomalous, very unusual and as we're moving into a time of changing climate, you know, it's happening and there are good indications that it's happening, but what does it mean for our region? What does it mean for the California current? What does it mean for upwelling and fisheries and, you know, whatever you want to talk about and the whales in this region? So, we need to get a much better idea of what is normal, how it works, so we can anticipate the changes that are going to come.

I maybe should mention to people that there are a number of web pages where you can get interesting oceanographic data.

Jennifer Stock: Oh, yeah. Please do share those. That'd be great.

John Largier: Yeah, well the...I'll tell you our one and from that you should be able to link to quite a variety of others because I don't want to tell you a bunch of them. Our part of this ocean observing system we call BOON, the Bodega Ocean Observing Node, the B-O-O-N. So, you can just Google BOON and it'll come up, but the URL is B-M-L, as in Bodega Marine Lab, dot UC Davis dot edu slash BOON and from there you can see some of the data we're collecting. Some of it is not showing up right now, but will soon and from there you should be able to link across a whole variety of other sources of data as well.

Jennifer Stock: And there's also the National Data Buoy Center. N-D-B-C....

John Largier: N-D-B-C, exactly.

Jennifer Stock: ...dot NOAA dot gov where you can click on regions to see buoys all around the country and hopefully, up and coming in the near future we'll be adding number 46095, the Cordell Bank Buoy, to that when that is able to get out there. So, if anyone's interested in tracking information real-time, live, seeing what the sea conditions are at, a lot of fishermen do this regularly. This is part of their daily, probably on the hour type of practice, is checking the weather and the winds and I know this past week it was just crazy. It'd be high and then low and then come up again, the winds. It was kind of unpredictable.

So, that's ndbc.noaa.gov. John, are there any last things you want to share about this upwelling system and the productivity here on the coast?

John Largier: Well, it is a fascinating time to be studying it. There is...they were getting so many different views of it and for me, what is most rewarding is to understand the movement of water and how it links in with what we as ocean people know about the ocean and when we have this experience of it and we...and, you know, the seasons we know it, but can we explain it and if we can explain it then we can deal better with the changes that are coming through climate change, but also through our own direct human action. You know, we influence the ocean, one, in a global sense by changing climate, but also in a local sense by things that we discharge into the ocean, by things we take from the ocean, and we can understand more of what we're doing. So, I like to practice environmental oceanography to focus on those environmental issues. What are some of the challenges to living sustainably on the planet and then what can oceanography tell us about how to address those issues and be better stewards.

So, that's really what excites me and happy to hear from anybody who wants to look at our website or if they have ideas or questions. The more interactions I have with people that love the ocean, the better.

Jennifer Stock: Wonderful. Do you want to share any contact information?

John Largier: Well, probably the...my email is jlargier@ucdavis.edu.

Jennifer Stock: And that's L-A-R-G-I-E-R.

John Largier: Exactly.

Jennifer Stock: At UC Davis dot edu and I'm sure through the BOON website too people can get you.

John Largier: Yes, I think they can, although, trying...I'm not sure exactly who they have there as a contact person. So, it's easier, the J-L-A-R-G-I-E-R at UC Davis, you'll get directly to me.

Jennifer Stock: Fantastic. Well, John thank you so much for sharing some time with us, really painting the picture of all the movement of water and why this place is so productive off the coastline here. It's really valuable. Thanks so much.

John Largier: Thank you, Jennifer. It's a pleasure and enjoyed talking with you.

Jennifer Stock: Hopefully, we'll have you on again sometime talk a little bit more about some of the larval settlement. I'm really interested in hearing a little bit more about that in regards to the marine protected areas that are...

John Largier: And the bays and estuaries.

Jennifer Stock: Oh, we'll have to...

John Largier: Fascinating places.

Jennifer Stock: Well, we'll have to have a show on bays and estuaries. So, for sure, I'll jump into the bays and the estuaries.

John Largier: That's right. I know that they're warmer.

Jennifer Stock: I know and that's actually good.

John Largier: Quite so.

Jennifer Stock: Well, thanks again. I really appreciate your coming on.

John Largier: Thank you.

Jennifer Stock: Take care.

John Largier: Buh-bye

(Music)

Jennifer Stock: Well, it's really exciting to hear just a little bit more about what are the forces affecting us here on the coast, the typical variability of the climate clearly has direct connections to the marine food web, the weather, it effects everyone and everything. Everything is connected and it's important to continue monitoring, to support the research in this field to help the scientists and managers cope with and plan for impacts on the ocean and the environment with global climate change on the horizon here.

(Music)

Jennifer Stock: This show is brought to you by NOAA's Cordell Bank National Marine Sanctuary, originally broadcast live, KWMR, community radio station of West Marin in California. You can find us on the web at KWMR.org. For more information about Cordell Bank National Marine Sanctuary and the National Marine Sanctuary Program, visit us on the web at sanctuaries.noaa.gov. Opinions on this show may or may not be the same as NOAA's. This show is meant to be educational in nature.